Digitisation to Presentation – Building Virtual Museum Exhibitions

Manjula Patel[1], Martin White[2], Krzysztof Walczak[3], Patrick Sayd[4]

1 UKOLN, University of Bath, UK
2 Centre for VLSI and Computer Graphics, University of Sussex, UK
3 Department of Information Technology, The Poznan University of Economics, Poznan, Poland
4 Image and Embedded Computers Laboratory, Commissariat à l'Energie Atomique, France

Abstract

We describe an innovative system designed for museums to create, manage and present multimedia based representations of museum artefacts in virtual exhibitions both inside and outside museums. Our system creates digital surrogates through a novel stereo photogrammetry system with little user interaction. The resulting 3D objects are refined using state-of-the-art 3D modelling software configured for ease of use by museum staff. A repository of such digital surrogates is managed in an XML enabled relational database and provides the basis for the creation and presentation of virtual museum exhibitions, allowing current museum websites to evolve from a 2D to a 3D multimedia-rich domain. In this paper, we discuss the modelling and refinement processes which are based on stereo photogrammetry and the creation and visualisation of virtual museum exhibitions using virtual and augmented reality techniques.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism

1. Introduction

The Augmented Representation of Cultural Objects or ARCO project [1] is funded within the Information Society Technologies (IST) Programme of the European Commission. The project began in October 2001 and has a duration of three years. The ARCO project is developing technologies that improve access to the vast amounts of cultural assets currently held by museums in their archives.

Recent advances in web technologies as well as virtual and augmented reality present an opportunity for museums to exhibit their resources online and therefore greatly expand the out-reach of these cultural heritage institutions. However, most current museum websites take a 2D-only approach, presenting the viewer with flat images of cultural artefacts with textual description—in effect a web based catalogue.

The ARCO project instead takes a multimedia approach by creating virtual representations of such artefacts and permits interaction with these digital surrogates. Virtual representations in ARCO are realized as extensible collections of media objects. For example, a simple virtual representation could indeed only include text and pictures. A collection of such virtual representations organised as a virtual online museum would look very similar to a standard museum web site. This is a key feature of ARCO related to socio-economic uptake of the technology, because it gives museums the ability to use the ARCO system to create simple online exhibitions as they do now. However, ARCO goes much further than this backwards compatibility. A virtual representation can include many types of media objects that represent elements of a museum artefact, e.g. 3D models, object movies, pictures, video, image sequences, textual descriptions and so on.

With this richer data model of digital representations of museum collections, museums can now build online virtual museums complete with interactivity in virtual or augmented reality environments. Such a virtual museum affords further advantages in that it is possible to display artefacts which would normally be inaccessible except to a select few; for example, exhibits which cannot be made available due to their fragile nature or because of other preservation issues or those which cannot be displayed simply due to a lack of physical space. ARCO will allow museums to increase their digital profile beyond simple implementation of web sites with pictures and text using a system that is designed for the museums and tested by museum pilot sites including the Victoria and Albert Museum in London and the Sussex Archaeological Society.

The ARCO project has synergies with several other European projects. The 3D-MURALE project [2] for

example, is developing and using multimedia tools to measure, reconstruct and visualise archaeological ruins in virtual reality, using as a test case the ancient city of Sagalassos in Turkey. The ARTISTE [3] project aims to build a tool for intelligent retrieval and indexing of high-resolution images. This project aims to have a core component that is compatible with existing standards such as Z39.50. ARCHEOGUIDE [4] has built a system providing information access at cultural heritage sites through the use of augmented reality, 3D visualisation, mobile computing, and multi-modal interaction techniques. The COVAX project [5] is developing a network of XML-based repositories as a distributed database to be accessed as a single database and will act as a meta-search engine, offering access to book references, finding aids, facsimile images, museum items, etc.

In order to bring to fruition our particular vision of a virtual museum, ARCO has adopted an interdisciplinary approach, integrating areas of vision and graphics, virtual and augmented reality, visualisation techniques, as well as database, metadata and web technologies. ARCO consists of both hardware and software components.

We have taken an iterative approach to the development of the ARCO system in order to enable our museum pilot sites to provide as much feedback as possible. The third prototype is imminent and will be followed by a final system which incorporates an integration phase to further bring together the various parts of the system. Describing the full ARCO system in detail is beyond the scope of this paper, instead we describe some of the major components that are focused around the usage and implementation of computer vision and graphics technologies.

The remainder of this paper is organized as follows. In Section 2, we first provide an overview of the ARCO system and discuss the major components and functional processes involved. In Section 3 we present the process of digitisation of artefacts using a custom built stereo photogrammetry system and their refinement into 3D models. In Section 4 we explain how the cultural object representations are stored and described in the ARCO database. Section 5 is a discussion of the creation of dynamically generated augmented content from a database containing digitised cultural artefacts. Finally, in Section 6 we conclude the paper and indicate future research directions.

2. Overview of the ARCO System

A major aim of the ARCO project is to develop technologies, systems and expertise required by museums to create virtual exhibitions or museums on the Web.

Before a museum can begin the process of creating a virtual exhibition using the ARCO system, as with all exhibitions, they must first decide which artefacts and associated materials they wish to exhibit. Careful consideration is given to potential digitisation methods that may be used to digitise the chosen artefacts. In general, the museum may already have digitised material, e.g. pictures, object movies, etc. ARCO is capable of importing these into the database and this may well be the first step.

When we consider the storage and management of virtual representations we use the abstract concept of a **cultural object**. A cultural object is represented in the ARCO system as either an **acquired object**, in this example the initial pictures and object movies or a **refined object**. A refined object is an interpretation of the cultural object— acquired or refined—created by a museum curator. An acquired or refined object consists of one or more media objects, as illustrated in Figure 1. A refined object may extend the original cultural object by adding new media objects, using modified versions of existing media objects, adding new metadata descriptions, etc.

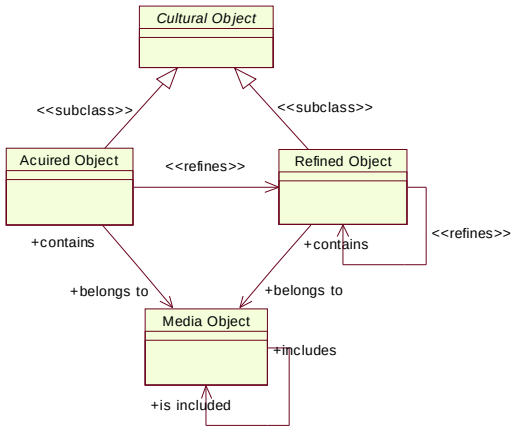

Figure 1 *The ARCO data model: cultural, acquired, refined and media objects*

A typical refinement might be the addition of a 3D model of the museum artefact. ARCO provides two complementary tools to create a 3D model of the artefact: a custom built stereo photogrammetry system called the Object Modeller [6], which is used for digitising small to medium artefacts, and a custom configured 3ds max framework called the Interactive Model Refinement and Rendering tool [7], which is used to refine the digitised model. The finished 3D model (which is only one media object in the virtual representation, or according to our data model in Figure 1, the refined object) is exported, as a VRML/X3D file [8] wrapped inside a special XML Data Exchange file to the database.

A user-friendly content management application (ACMA – ARCO Content Management Application [9]), equipped with a set of data managers, allows the museum user to

manage all aspects of the database including the virtual representations of cultural objects, virtual exhibitions, and visualization templates.

Final contents of virtual exhibitions are then dynamically generated using X-VRML visualization templates [11, 12, 13]. The exhibitions may consist of both 3D VRML/X3D virtual galleries and 2D multimedia web pages and may be accessed by either a web browser (over the Internet, or on a touch screen display in the museum) or through a table-top augmented reality environment in the museum using augmented reality interfaces – ARIF.

ARCO components are connected as an open architecture using the XML Data Exchange format (XDE) to provide for inter-connectivity and interoperability. Figure 2 illustrates the major components of the ARCO system. It is divided into three conceptual areas depending on the user's interaction with the data. The producer side is responsible for creation of the multimedia content. The server side is responsible for both storing the multimedia representations, including metadata, as well as preparing dynamic presentations to be displayed by the consumer side.

3. Creating and Refining 3D Models

The Object Modeller component [6] is based on image analysis. For the first prototype, the project studied existing industry standard software in the form of ImageModeler [14] and PhotoModeler [15]. This solution is cheap and any standard camera is convenient for the image acquisition. The 3D model can be extracted by the user from a collection of images of the artefact. The user has to manually select points in the images to design the shape of the artefact. In the first ARCO museum user trials, several simple 3D models of various artefacts were built by museum staff using this solution.

However, the 3D resolution of the resulting model depends on the point selections made by the user. 3D reconstruction of most artefacts requires that a huge number of points be selected on the object's surface to obtain a sufficient level of detail. It is impractical to expect a museum to model a whole collection in this manner.

To overcome this limitation, we are developing in ARCO a custom object modelling system which respects the following requirements:

- the system should be easy to use for museum staff who are not experts in 3D measurement;
- there should be a reduction in the amount of interaction to speed up the reconstruction;
- the result should be an accurate 3D model of the artefact in terms of shape, texture and resolution.

The solution we propose includes both hardware and software. We are designing a stereo photogrammetry system [20, 21], incorporating two digital cameras, for image acquisition. A user interface has been developed to drive the acquisition, launch the modelling process, visualize and enhance the resulting model and finally export it to the database in VRML/X3D format.

The stereo reconstruction of the surface which is visible on the two acquired images is fully automated. The reconstructed 3D mesh can be interactively refined by suppressing some vertices or faces or by smoothing the surface. From a series of such pairs of images, a complete 3D mesh is created by merging all the stereoscopic reconstructions, as shown in Figure 3.

The Object Modeller, illustrated in Figure 4 and developed in ARCO, also provides a tool for automatic texture extraction from images. The output is a textured 3D polygon mesh of the digitised artefact.

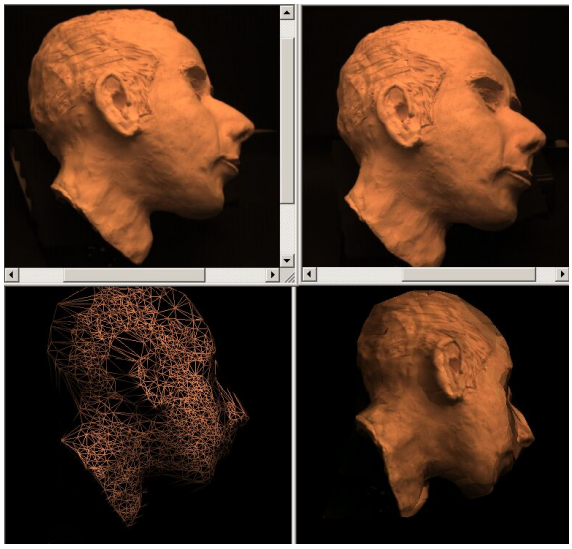

Figure 3 *ARCO Object Modeller: A pair of stereoscopic images, and the generated 3D wire-frame and textured models*

Since the 3D modelling process in ARCO is mostly automatic, some errors may hit both the generated shape (imprecision and missing parts) and the extracted texture (light variation, occluding objects, etc.). Consequently, a refinement stage is necessary to improve the model geometry and the texture rendering.

3D models generated by the Object Modeller are refined in the Interactive Model Refinement and Rendering (IMRR) tool [7]. This tool, based on the industry standard 3ds max framework [16], is custom configured to provide a simple user-friendly model refinement interface for the museum

user. Refinements, such as smoothing the object geometry, reducing polygon count for Internet based rendering, re-applying lighting and repairing missing parts can be performed in the IMRR tool.

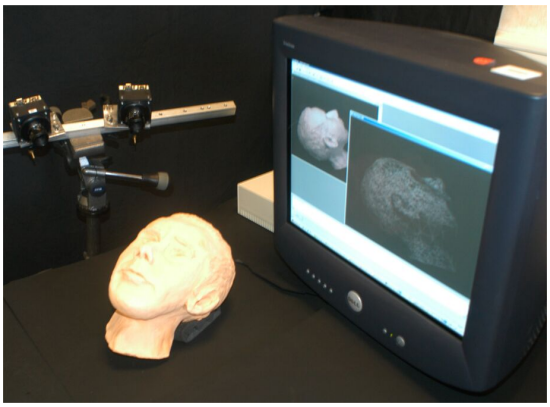

Figure 4 *The custom built Object Modeller System*

The IMRR tool also provides other functionality such as database connectivity to browse cultural objects, import and export of 3D models in the XDE format and acquisition of models generated by other methods such as laser scanning and mechanical scanning. Figure 5 illustrates the database connectivity plug-in that allows the museum user to search the database for a cultural object to refine. The database layout reflected in the top left window is similar to the layout seen in the Cultural Object Manager in ACMA, presented in Figure 6 and described in Section 4.

4. Storing and Describing Cultural Objects

All persistent data produced and used by the ARCO system including the virtual representations of cultural artefacts, associated media objects and metadata are kept in the ARCO database implemented on top of an XML [17] enabled object relational database management system. Museum staff can import, export and manipulate the data stored in the database in a user-friendly way by the use of the ARCO Content Management Application – ACMA [9], illustrated in Figure 6.

The ACMA tool is composed of several data managers with the most important being:

- *Cultural Object Manager* – for managing all data related to virtual representations of cultural objects,
- *Presentation Manager* – for managing virtual exhibitions,
- *Template Manager* – for managing X-VRML visualization templates, and
- *Template Object Manager* – for managing all multimedia data used in virtual exhibitions but not related to cultural objects.

An important feature of the ARCO database and ACMA tools is extensibility which allows museums to add new types of media objects without modifying the database schema or application software. This means that museums are able to extend the set of multimedia objects used to represent cultural objects to reflect their current or future practices.

ACMA allows management of metadata descriptions of cultural objects and the associated media objects. The descriptions are stored using a metadata schema developed by the project, the ARCO Metadata Schema or AMS [18, 19]. The AMS is used at all ARCO stages from digitisation of a museum artefact, through refinement and storage to visualisation of the artefact in a virtual or augmented reality environment.

5. Dynamic Virtual Exhibitions

ARCO visualizes the virtual representations of museum artefacts in Augmented and Virtual Reality Interfaces built dynamically with X-VRML visualization templates [11, 12, 13, 19]. X-VRML is a high-level language enhancing virtual reality standards such as VRML and X3D [8] with dynamic modelling capabilities. The dynamic modelling technique enables development of dynamic database-driven virtual reality applications by building parameterised models (templates) of virtual scenes that constitute the application, and dynamic generation of instances of the virtual scenes based on the models, data retrieved from a database, current values of model parameters, query provided by a user, user privileges or preferences.

The cultural object representations in ARCO may be visualized in a network of interconnected virtual exhibition spaces composed of both 3D virtual galleries and 2D multimedia web pages. The form of visualization depends on the X-VRML templates selected by the museum curator while building the exhibition. A number of different templates can be used to present the same contents in different ways.

The ARCO content management application allows museum users to build virtual exhibitions by simply assigning cultural objects and X-VRML visualization models to virtual exhibition spaces as illustrated in Figure 7. The objects contained in an exhibition space are visualized using the X-VRML model either explicitly assigned to the space or inherited from a super-space. Parameterisation of the models allows museum users to further differentiate visualizations in different spaces. Depending on the set of parameters pre-configured by the museum curator an X-VRML visualization model may generate a fixed virtual

gallery, a user-customisable virtual gallery, or a search interface.

To provide maximum flexibility and to avoid repeating the work on designing exhibitions for use within different contexts, ARCO uses a concept of presentation domains. Presentation domains correspond to different environments in which the virtual exhibitions created by ARCO can be used. By using presentation domains museums may create different presentations of the same content for use in different environments. For example, a collection of cultural objects should be presented differently when accessed by a Web browser from the Internet, on a touch screen display installed within the museum, or in a table-top Augmented Reality environment. Three different presentation domains corresponding to these scenarios are used in the second and third ARCO prototype system:

- Web Remote domain,
- Web Local domain, and
- Augmented Reality Local domain.

Since the list of presentation domains is extensible, the museums may create new domains when needed.

Figure 8 shows an example of a touch-screen display which could be used within a museum. A collection of cultural objects displayed in a 3D virtual gallery and 2D web interface is presented in Figures 9 and 10.

The creation of the final content constituting virtual exhibitions is performed dynamically by the ARIF X-VRML Server implemented as an extension to a standard HTTP server. An overall architecture of the ARIF X-VRML Server is presented in Figure 11. The server consists of the X-VRML Module responsible for processing X-VRML templates and the ADAM – ARCO Data Access Module responsible for retrieving binary objects from the database

6. Conclusions and Further Work

The ARCO project has developed tools and techniques which provide the potential for museums to publish their collections of artefacts in multimedia virtual exhibitions including 3D virtual galleries. This allows museums to raise and maintain their digital profile through the use of cost effective technology. The creation of a database of digital surrogates provides a foundation for creating multiple virtual exhibitions such that an artefact may appear in more than one exhibition simultaneously. Further, the use of a multimedia approach promises to enrich the online experience of those browsing through virtual museum archives, offering a motivation to boost attendance by museum visitors.

In this paper, we have concentrated on describing the development of processes for creating and refining 3D models of cultural artefacts, as well as their visualisation using virtual and augmented reality. ARCO is also defining a metadata element set that describes the ARCO data model from digitisation to visualisation.

Feedback from our museum pilot sites will continue to be solicited through Museum User Trials, which take place following the development of each prototype. The project has reached the stage of implementing the third prototype, which will be followed by the final system in six to twelve months time. Finally, the ARCO system and components will be demonstrated at the Museum Association Conference in Brighton, October 2003.

Figure 8 *Example of a touch-screen interface within a museum*

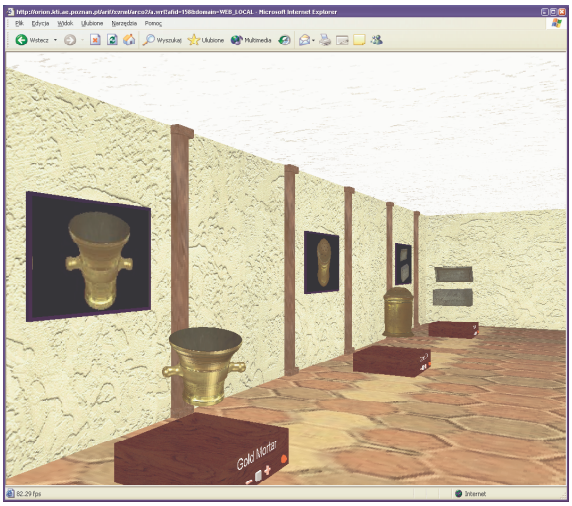

Figure 9 A collection of cultural objects displayed in a 3D virtual gallery

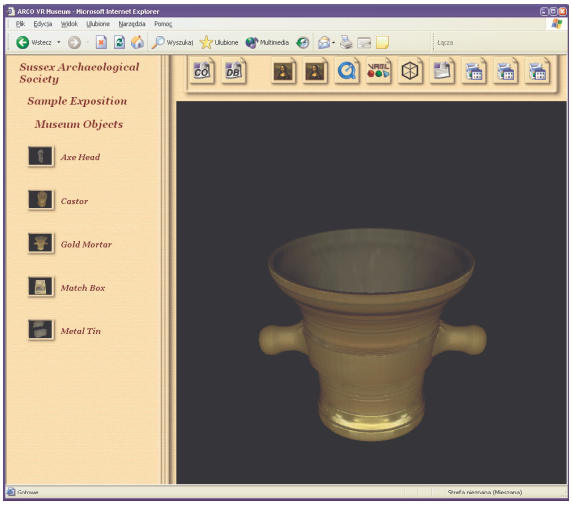

Figure 10 A collection of cultural objects displayed in a 2D web interface

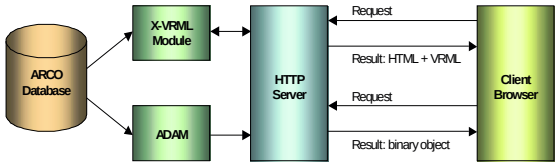

Figure 11 *Architecture of the ARIF X-VRML Server*

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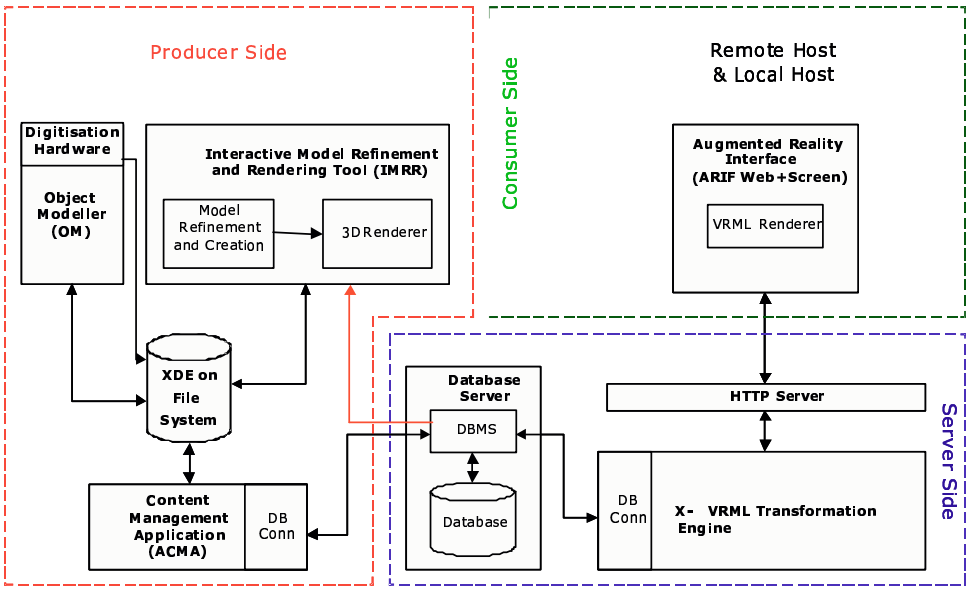

Figure 2: *Major components of ARCO system architecture*

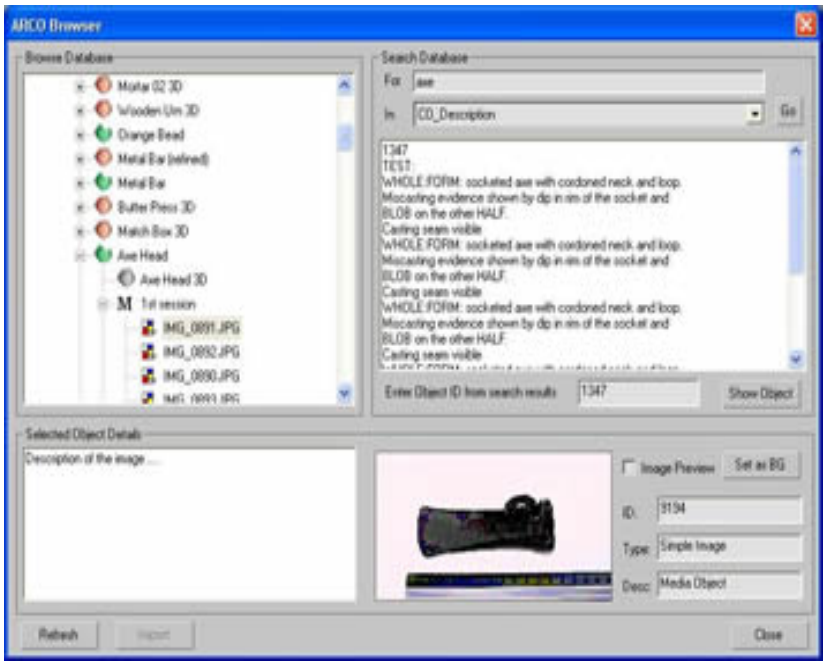

Figure 5 *IMRR database plug-in for browsing cultural objects already in the database*

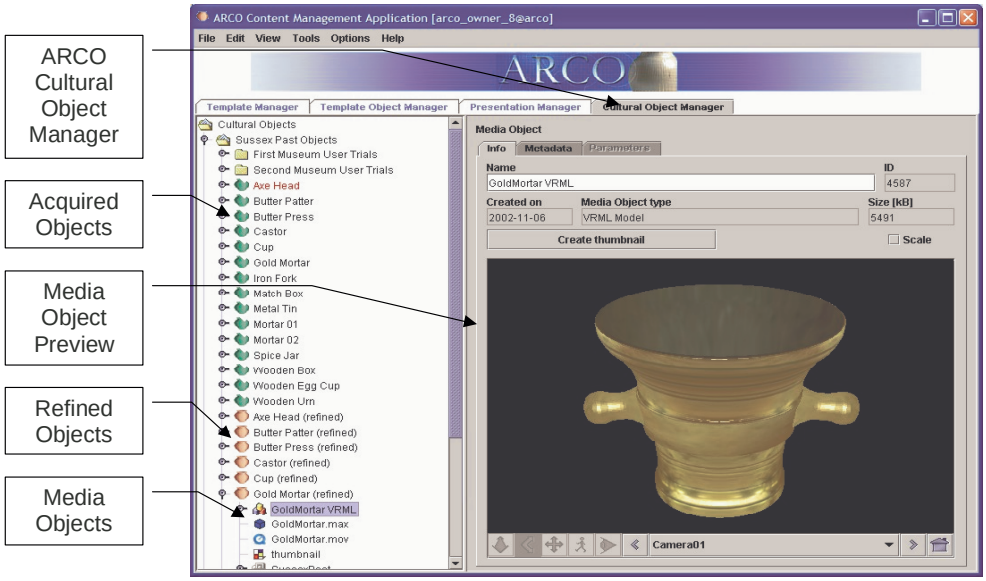

Figure 6 *ARCO Content Management Application – Cultural Object Manager displaying a 3D model of an artefact*

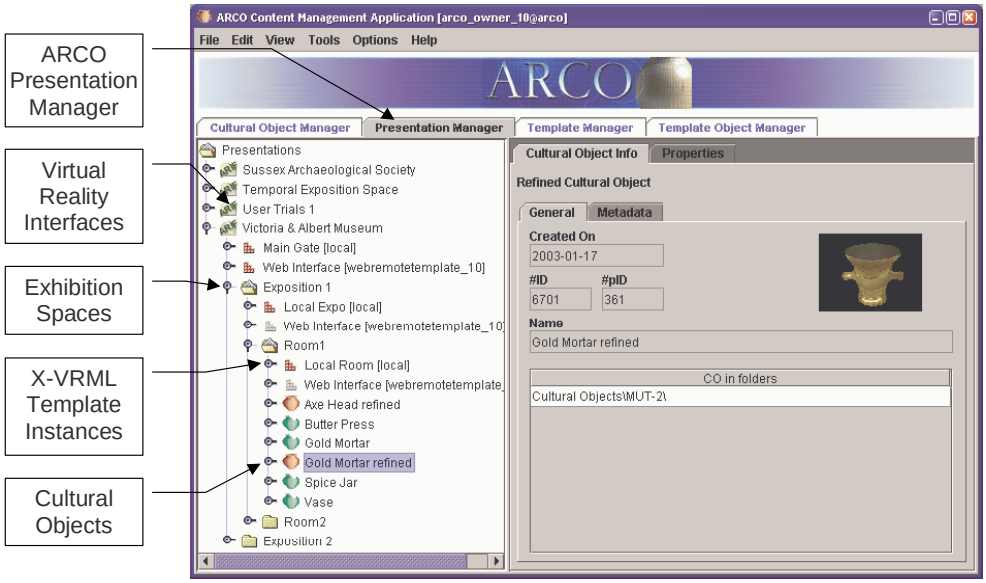

Figure 7 *Creating a virtual exhibition in ACMA*